

GLOBAL PRECIPITATION MEASUREMENT UPDATE

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Abstract-Global Precipitation Measurement (GPM) is an international cooperative program whose objectives are to (a) increase understanding of rainfall processes, and (b) make frequent rainfall measurements on a global basis. The National Aeronautics and Space Administration and the Japanese Aviation Exploration Agency have entered into a cooperative effort for the formulation and development of GPM. This effort represents a continuation of the partnership that developed the highly successful Tropical Rainfall Measuring Mission (TRMM). Several activities discussed within this paper reflect the maturity of the Project Formulation activities that have been completed, and forms a basis for the anticipated receipt of approval to begin Project Implementation during the forthcoming year.

I. INTRODUCTION

Precipitation measurements obtained frequently and on a global basis are used by climate modelers to infer latent heat transfers, hydrologists to infer water collection over large basins, and weather modelers and forecasters to improve their understanding of weather processes and the accuracies of their predictions. Knowledge of cloud dynamics facilitates advancements in the understanding of rainfall processes and aids in the further refinement of models. The Tropical Rainfall Measuring Mission (TRMM), launched in November 1997, demonstrated both the capability of making rainfall measurements from space, and the value of those measurements to the scientific and meteorological communities. The National Aeronautics and Space Administration (NASA) of the United States and the Japanese Aerospace Exploration Agency (JAXA) are in the process of implementing a successor mission to TRMM called Global Precipitation Measurement. In comparison to TRMM GPM will expand the measurements of rainfall and rainfall processes from the tropical regions to global measurements, increase the frequency with which measurements are made, and provide significant improvements in the measurement parameters. This paper, and others presented at IGARSS 2005 [1,2], will provide a brief overview of the GPM Program, and discuss the status of its major elements.

II. BACKGROUND

Global Precipitation Measurement is structured to be an evolution and expansion of the Tropical Rainfall Measuring

Mission (TRMM). TRMM is an on-going, joint mission between the United States and Japan that is still taking rainfall measurements after nearly eight years of successful on-orbit operation. The primary instruments onboard the TRMM spacecraft for rain measurement are the Precipitation Radar (PR) and the TRMM Microwave Imager (TMI). The PR is a nadir-pointing, single-frequency, phased array, electronically steered radar, operating at 13.8 Gigahertz (GHz). The radar's measurement footprint is 4.5 km in diameter, and is electronically steered 17° to either side of the spacecraft nadir, providing a measurement swath 215 km from side-to-side. Within each measurement footprint, the PR takes range-gated measurements in 250 meter layers, thus providing information about the cloud's vertical structure. The TMI is a passive, conical-scan, microwave radiometer that takes measurements in both the horizontal and vertical polarizations for microwave emissions at 10.65, 19.35, 37.0 and 85.5 GHz, and in only the vertical polarization at 21.3 GHz. Noteworthy characteristics of the TMI include both its broad measurement swath of 760 km, a constant earth incidence angle of 52.8° for all measurements, and constant-size measurement footprint at each measurement frequency regardless of scan position. TRMM rainfall retrieval algorithms show good (and improving) correlation between rainfall estimates that are obtained independently by the PR and the TMI. Global Precipitation Measurement has been structured to build upon the rainfall measurement approach proven by TRMM, with important additions to address the specific objectives of GPM.

III. GPM STRUCTURE

GPM has been structured with the specific objectives of (1) taking measurements of cloud structure and dynamics in order to provide a better understanding of rainfall processes, cloud microphysics and macrophysics, and (2) taking frequent, accurate, rainfall measurements on a global basis. In support of these objectives GPM has identified four major elements that are necessary for the development of an effective and viable program:

- 1) A Core spacecraft that makes accurate rainfall measurements, collects information on cloud dynamics and rainfall processes, and serves a calibration reference for other instruments used within the GPM Program for taking rainfall measurements,

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2) A multi-satellite constellation, with each satellite equipped with a passive microwave radiometer that measures rainfall and other forms of precipitation over broad measurement swaths,

3) A Ground Validation (GV) Program that provides ground truth verification and measurement validation at various locations on the earth that are representative of precipitation events associated with different climates and geo-locations (e.g., tropical, oceanic),

4) A Precipitation Processing System (PPS) that collects and processes the measurement data obtained by the Core and the constellation of spacecraft, and that disseminates precipitation data products to the user community.

These areas will be discussed in the following sections.

IV. CORE SPACECRAFT

The Core spacecraft will be launched into a 65° high inclination orbit at a 407-kilometer altitude. While this orbit excludes the Arctic regions (the Arctic Circle lies at $\sim 66\frac{1}{2}^{\circ}$), it includes almost all regions on the earth where liquid precipitation occurs. As mentioned previously the Core spacecraft will carry a Dual-frequency Precipitation Radar and the GPM Microwave Imager.

During 2004 a decision was made to procure the Core spacecraft from industry via the Goddard Space Flight Center Rapid Spacecraft Development Office. Three vendors completed preliminary spacecraft design studies, and a down-select to two vendors for a further refinement of their designs will take place during 2005. During 2006 one vendor will be selected to complete the spacecraft design, and fabricate the bus. Fig. 1 is an illustration of one design concept. The GMI instrument is shown on top of the spacecraft, to the left front; the two radars that comprise the DPR are the large structures on the nadir side of the spacecraft.

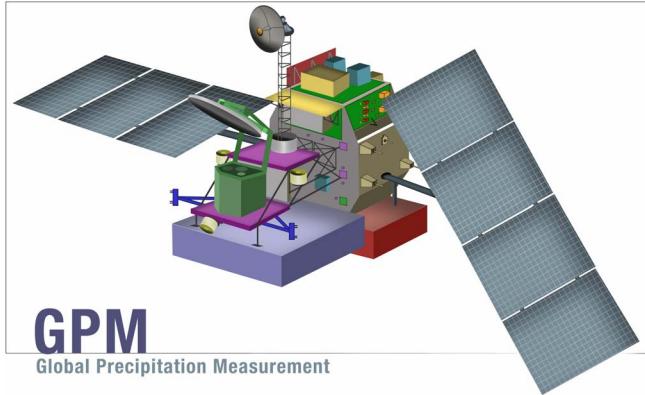


Figure 1. Core spacecraft

V. GPM INSTRUMENTS

There will be two instruments on the GPM Core spacecraft, the GPM Microwave Imager (GMI) (Fig. 2), and the Dual-frequency Precipitation Radar (DPR). The GMI will be a conical-scan, nine channel passive microwave radiometer. The configuration of this instrument provides a broad measurement

swath (850 km), and like the TMI, maintains a constant earth incidence angle of 52.8° and a constant footprint size for each measurement channel regardless of scan position. The GMI will have a 1.2 meter diameter main reflector, which is twice the diameter of the TMI. This larger reflector will reduce the area of each measurement footprint to approximately one-quarter of the area of the TMI. The smaller footprint provides a significant reduction in measurement uncertainty arising from inhomogeneous surface conditions, such as may be encountered during thunderstorms.

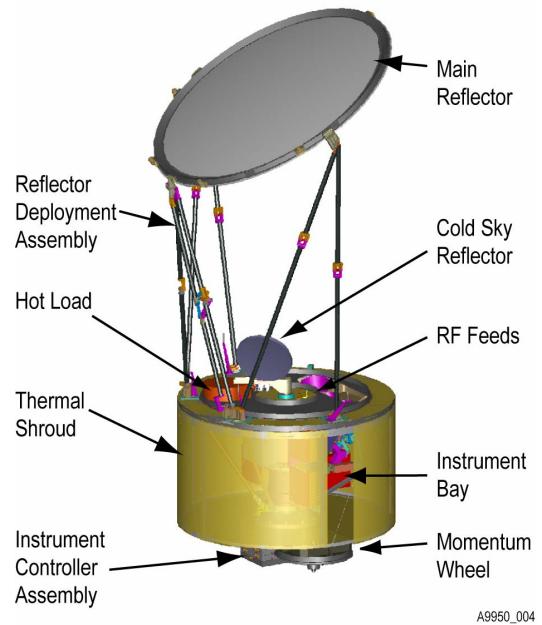


Figure 2. GPM Microwave Imager

In March 2005 a contract was awarded to Ball Aerospace and Technologies Corporation for the design and fabrication of this instrument. It should be noted that GMI is designed to be a very well calibrated instrument [1].

The Dual-frequency Precipitation Radar (DPR) will provide high resolution, high precision measurements of rainfall, rainfall processes, and cloud dynamics. The DPR is essentially two radars, the Ku-PR and the Ka-PR. The Ku-PR operates at 13.6 GHz and is of similar design to the TRMM Precipitation Radar. The Ka-PR is based upon the PR's design but operates at 35.55 GHz, and the size of its antenna has been selected such that its measurement footprint matches the footprint size of the Ku-PR. Each radar uses a phased array, slotted wave guide antenna. Both radars of the DPR can be electronically steered up to 17° to either side of the spacecraft nadir, providing a 245 km measurement swath. The Ka-PR also has a selectable high sensitivity mode which provides an interlacing scan with a swath width of 120 km; this high sensitivity mode will aid in the measurement of light rain and snow. The two phased array antennas will be aligned so that identically sized co-incident measurement footprints of 4.5 km diameter can be taken. The wide separation in operating frequencies of the two radars provide differential reflectivities of the transmit pulses from rain and cloud structures, allowing inferences to be made about

drop size distributions and rain-rates. The DPR is in advanced development at JAXA.

Co-location of the DPR with the GMI provides the opportunity to use the DPR to make high-precision measurements of the clouds, cloud structure, rainfall and rainfall processes, and to compare those high-precision radar measurements with the radiometric measurements made by GMI. This comparison will improve understanding of the physical basis for the radiometric measurements, and help in the development of more accurate retrieval algorithms.

With the Core spacecraft flying in a low altitude, high-inclination orbit, and most members of the GPM constellation flying in polar orbits, the Core spacecraft will cross under the orbits of the other members of the GPM constellation. On those occasions when the two spacecraft cross at the same time, opportunities for comparing earth scene measurements taken simultaneously, or near simultaneously, by the suite of instruments on the Core spacecraft with radiometric measurements taken by the constellation spacecraft exist. In this comparison process the well-calibrated GMI will serve as the calibration reference for the constellation radiometers. Once the constellation radiometer has been calibrated against the GMI, it is anticipated that measurements made by that instrument can be interpreted vis-a-vie previous GMI-DPR measurements to provide a better understanding of the rainfall processes recorded by the constellation radiometers. Thus this calibration reference may provide a means for transferring the detailed information on cloud structure and rainfall obtained by the DPR to other members of the GPM constellation. This inter-comparison process, over time, will result in substantial improvements in the accuracy of rainfall retrievals obtained by the individual microwave radiometers, and collectively, by the GPM Constellation.

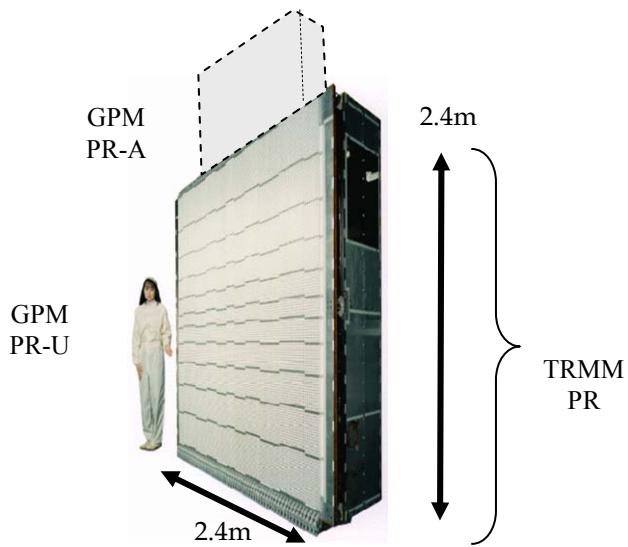


Figure 3. Dual-frequency Precipitation Radar

VI. GPM CONSTELLATION

One of the objectives of GPM is to have multiple spacecraft in-orbit to make rainfall measurements on a global basis. As the number of microwave radiometers available on-orbit increase, the interval of time between measurements at each location on the ground decreases (i.e., the revisit time shortens – Fig. 4). Simulations undertaken by NASA suggest that a three-hour revisit time can be achieved with the use of eight spacecraft equipped with conical-scan microwave radiometers.

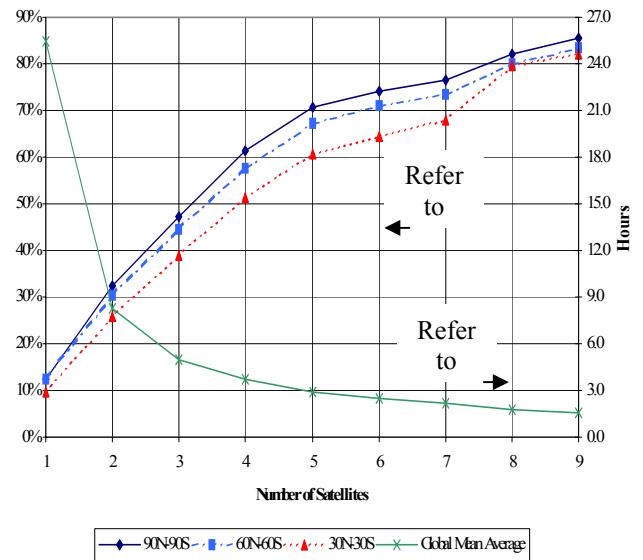


Figure 4. Percent Sampled Bins and Global Mean Revisit Time vs. Number of Satellites

The spacecraft in the GPM constellation may be specifically developed to support GPM, such as the Core spacecraft, or may be developed primarily for other purposes (e.g., weather satellites), but have a rainfall measurement capability. The following are candidate members of the GPM Constellation:

- Core spacecraft,
- Constellation spacecraft provided by NASA (Fig. 5),
- EGPM provided by the European Space Agency (ESA), and equipped with a nadir-viewing, pencil-beam cloud radar and a microwave radiometer,
- Megha Tropiques, a joint French and Indian low-inclination, tropical rainfall measurement satellite,
- Three National Polar-orbiting Operational Environmental Satellite System (NPOESS) weather satellites, each equipped with the Conical-scan Microwave Imager-Sounder (CMIS),
- Possible additional international GPM contributions,
- Other satellites currently in planning or whose operational life may extend into the GPM-era, including GCOM-B1 (JAXA), DMSP F19/20 (USA), FY-3 (China).

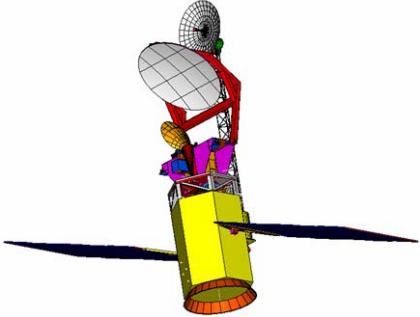


Figure 5. NASA provided Constellation spacecraft

VII. GROUND VALIDATION SYSTEM

The GPM Program is in the process of developing an extensive, worldwide Ground Validation (GV) System. This system will help characterize errors, quantify measurement uncertainty, and provide a physically-based measurement standard against which to assess performance and aid in the improvement of the science retrieval algorithms. Planning is currently in progress for the development of a worldwide GV network. Such a network is necessary because of the variability in the types of rainfall, and the effects that latitude and regional geographical features have upon rainfall and its frequency. At least 7 heavily instrumented GV “super-sites” and a large number of standard GV sites and regional rain gauge networks are expected to be placed into operation by the United States and its partners [2].

VIII. PRECIPITATION PROCESSING SYSTEM (PPS)

The GPM Precipitation Processing System (PPS) will be a science data processing system dedicated to the needs of GPM. The PPS will collect and process rainfall data from the Core

spacecraft and the GPM constellation. The data from the DPR will initially be processed by JAXA and then provided to the PPS. The PPS will be the central data processing and distribution facility for all members of the GPM Program. The PPS will also receive inputs from the Ground Validation Program, and provide calibration and error corrections to the GPM data products. The PPS is currently under development with a design based upon the TRMM Science and Data Information System (TSDIS); portions of the PPS prototype system are expected to be demonstrated in late 2005.

IX. SUMMARY

In summary, the Global Precipitation Measurement Program is a major collaborative effort between NASA, JAXA, the European Space Agency and other national and international partners. The objectives of this program are to build upon and continue the research initiated by TRMM in the areas of global climate modeling, understanding cloud dynamics and improving global and regional weather modeling and prediction. GPM has several major elements, including a multi-national space segment, a ground validation system and a precipitation processing system. Within NASA the Project Formulation Phase for GPM has matured during the past year, and activities are in progress that will prepare the Project for Implementation. Noteworthy activities include the award in early 2005 of the GMI production contract, and the anticipated award of a contract for the Core spacecraft in 2006.

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